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Art. XIII.—*The Muckleford Fault in the Guildford-Strangways Area (near Castlemaine, Victoria.)*

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I. Introduction and Acknowledgments.

The Muckleford Fault was postulated by Harris and Thomas (9) as a north and south fault which in the area between Castlemaine and Newstead separates Lancefieldian beds on the west from Darriwilian on the east. Owing to the nature of the country the line of fault can be traced only approximately in the field, though the palaeontological evidence in support of it is strong. North-west of Guildford, however, excavations by the Guildford Plateau Mining Company exposed a fault which was noticed by the Director of Geological Survey (Mr. W. Baragwanath) who drew my attention to it. My thanks are due to Mr. Baragwanath for the opportunity of studying the occurrence. I am also indebted to Mr. G. G. Dunstan for much general information; to Mr. Ray, the manager of the mine, for many acts of kindness during the progress of my work; and lastly to Dr. W. J. Harris, who placed his knowledge of the graptolites of the area at my disposal.

II. Physiography.

The area north of Guildford consists of a basalt plateau (Fig. 1) about 900 feet above sea level, with steep and—in places—precipitous slopes to the two lateral streams, the Loddon River on the south and the Muckleford Creek on the west. These separate the plateau from the rolling hills of Ordovician rocks

on the south and west, while the basalt thins out on the slopes of similar hills to the north. The streams flow about 200 feet below the surface level of the plateau. The Muckleford Creek, after a general southerly course, turns to the west before joining the Loddon, flowing through a narrow valley. The Loddon, flowing towards the west, has a flat-bottomed valley. The plateau and the alluvial flats along the Loddon are the fertile areas of the district. The Ordovician hills are generally tree-covered. Apart from the line of gentle eastward slope north of the Guildford Plateau shaft, to be discussed later, the plateau slopes generally towards the west.

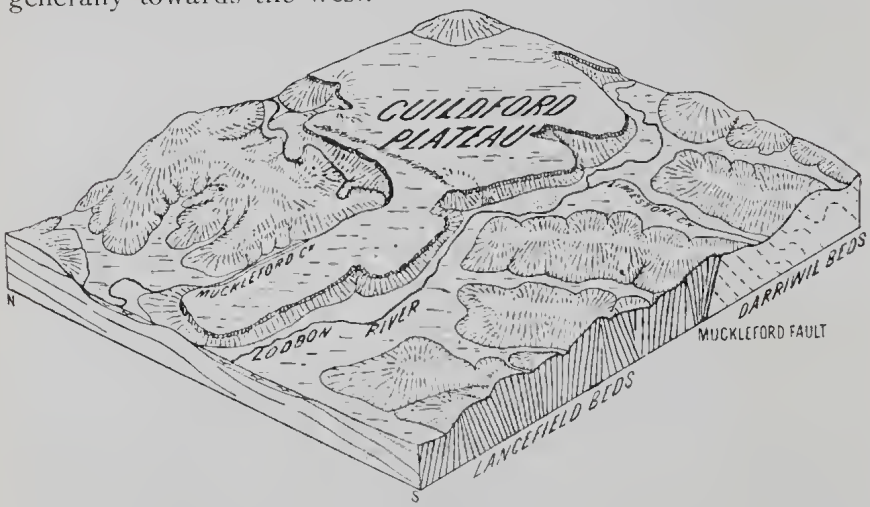

Fig. 1.

III. Previous Work.

Q.S. 15 N.E. of the Geological Survey of Victoria (by Ulrich and Aplin) is the only detailed geological map of the area. The physiography and distribution of the various groups of rocks are very accurately shown, even though this sheet was published in 1864. Later work has increased our knowledge of the graptolite succession in the area. Apart from this Quarter-sheet the only other detailed references to the geology of the area are to be found in mining reports.

IV. Geology.

The rocks of the area are Lower Ordovician sandstones and shales, covered in part with a relatively thin mantle of basalt and river gravels or "wash" of pre-basaltic age. (Figs. 2 and 3).

The age of the Ordovician rocks is known from their contained graptolites, while from analogy with similar occurrences in other parts of Victoria the gravels are referred to Tertiary times (Miocene to Pliocene).

(i) Lower Ordovician Rocks.

The Lower Ordovician rocks consist, as is usually the case in Victoria, of sandstones ranging from coarse- to fine-grained, with intercalated shales and mudstones. Their strike is slightly to the west of north; they are inclined at a high angle (in places they are almost vertical), and they are closely folded, as may be seen from the sections exposed along the Muckleford Creek and in railway and road cuttings. The high angles of dip make it impossible to trace individual folds for any distance.

Many of the graptolite localities were first found by Harris(8) who showed that the beds along the railway line between Guildford and Limestone Creek were of Darriwilian age. Later Harris and Thomas(9) recorded additional localities and showed that the Muckleford Fault formed a dividing line between Lancefieldian and Darriwilian. The most westerly outcrop at which graptolites were found along the Castlemaine-Newstead railway line (87 m. 52 ch.) yielded the following forms indicating a low Darriwilian zone (D4):—

Isograptus caduceus var. divergens Harris, and other variants.
Cardiograptus morsus Harris and Keble.
Oncograptus upsilon var. biangulatus (H. and K.).
Didymograptus v-deflexus H. and K.
Trigonograptus sp. (probably T. ensiformis Hall).
Phyllograptus sp.

Oncograptus beds also occur on the north and south road south of the railway crossing at 87 m. 33 ch., and *Cardiograptus morsus* beds at 86 m. 57 ch. on the railway and further east. Poorly preserved graptolites may also be obtained from the soft shales along the Loddon below the outlier of Tertiary gravels, the commonest forms being Darriwilian varieties of *I. caduceus*.

The spoil heap of the Guildford Plateau mine contains many fragmentary graptolites. The mudstone here, however, is doubly cleaved, making the extraction of specimens difficult. The following were identified:—

Isograptus caduceus var. maximo-divergens Harris.
I. caduceus var. divergens Harris.
I. forcipiformis (Rued.).
Didymograptus v-deflexus H. and K.
Didymograptus spp.
Tetragraptus serra Brong.
Tetragraptus sp. (cf. headi Hall).

Although *Oncograptus* was not found, the assemblage points to a low Darriwilian horizon (probably D5).

Two other outcrops yielded assemblages indicating passage-beds between the D3 and D2 zones, or perhaps what might better be called the basal beds of the D2 zone (zone of *D.* (*Glyptograptus*) *austrodentatus*). Previously this assemblage had been

recorded only from the Brisbane Ranges. One of these localities, originally discovered by Mr. Baragwanath, is the spoil-heap of the old Plateau shaft, which was sunk through basalt in Allot. 26, Guildford. The following forms are present:—

Isograptus caduceus var. maximo-divergens Harris.
I. caduceus var. divergens Harris.
I. hastatus Harris.
Skiagraptus gnomonicus (Harris and Keble).
Cardiograptus morsus H. and K.
Tetragraptus serra Brong.
Tetragraptus spp.
Goniograptus speciosus T. S. Hall.
Trigonograptus ensiformis J. Hall.
Phyllograptus cf. nobilis H. and K.
Didymograptus v-deflexus H.
Diplograptus (Glyptograptus) austrodentatus H. and K.

The Grand Trunk tunnel dump yielded:—

Cardiograptus morsus H. and K. (long narrow variety).
Didymograptus spp.
Tetragraptus sp.
Trigonograptus cf. ensiformis J. Hall.
Phyllograptus cf. nobilis H. and K.
Loganograptus sp.
Variants of I. caduceus.

All these localities are east of the Muckleford Fault and show the strata ascending eastward towards the centre of the Muckleford synclinorium which Harris and Thomas place as near the 85½ mile-post on the railway.

To the west of the fault in the Lancefieldian belt the search for graptolites was less successful. Lancefieldian forms (L1) (*Tetragraptus decipiens* T. S. Hall, *T. approximatus* Nicholson, and *Clonograptus* sp.) occur at the locality marked as Note 25 on Q.S. 15 N.E. The strike of this band would pass to the west of the Guildford Plateau mine. Lithologically the rocks east and west of the Muckleford Fault resemble each other, although waxy brown shales common to the Lancefieldian are missing from the Darriwilian. Generally speaking, hard sandstones predominate in the west and thick shales with softer sandstones in the east, with the result that surface relief is greater in the west. The differences, too slight to enable individual outcrops to be separated, give a regional distinction. This, together with the strike of the Lancefieldian band recognized, and the occurrence of Darriwilian graptolites near the Guildford Plateau mine, makes it reasonably certain that the fault exposed in the excavation at the mine is on the line of the Muckleford Fault. This Fault, which is responsible for the absence at this locality of the whole of the Bendigonian and Castlemainian series, must be, as far as one can estimate, of the order of 4,000 feet.

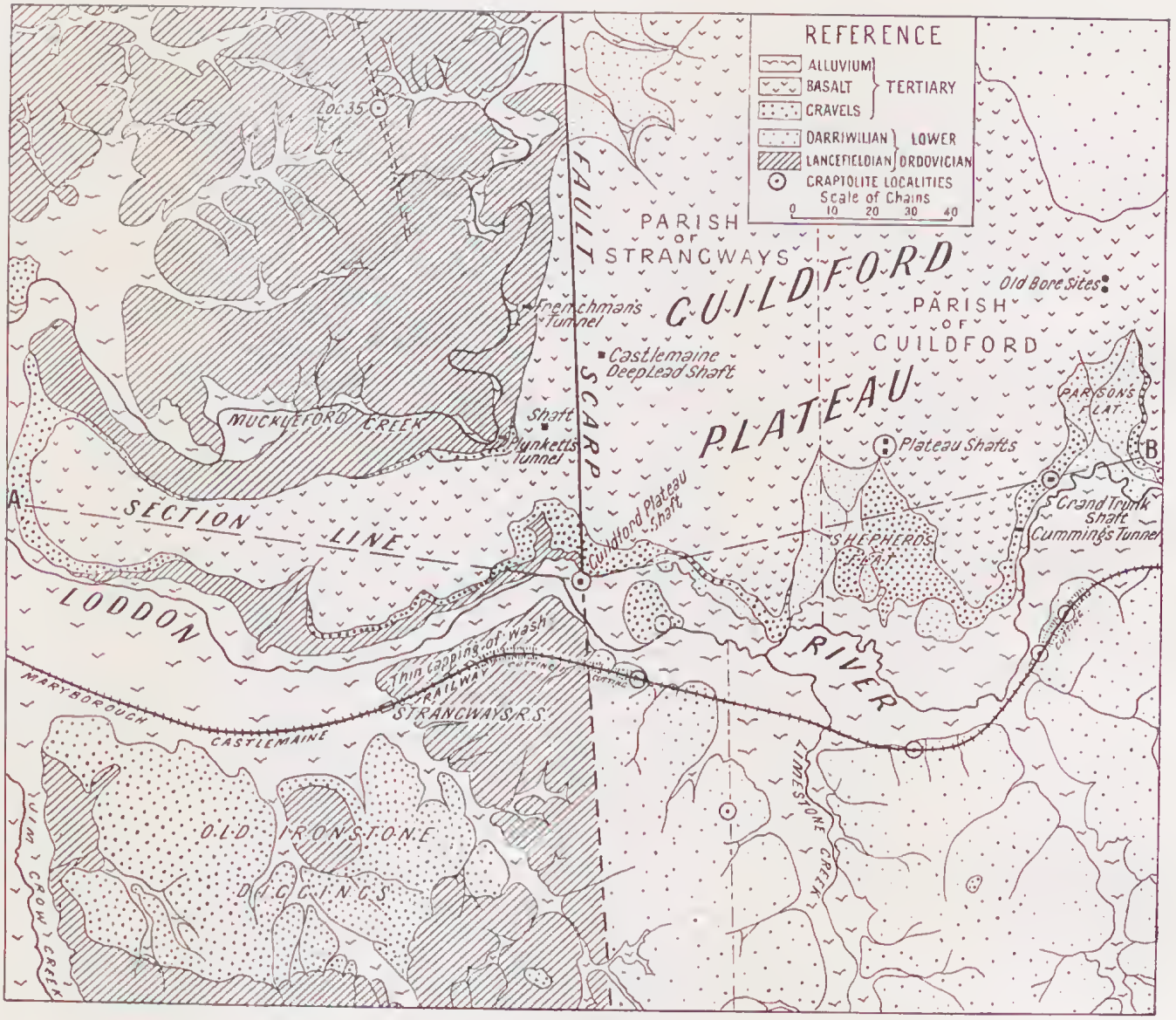

Fig. 2.

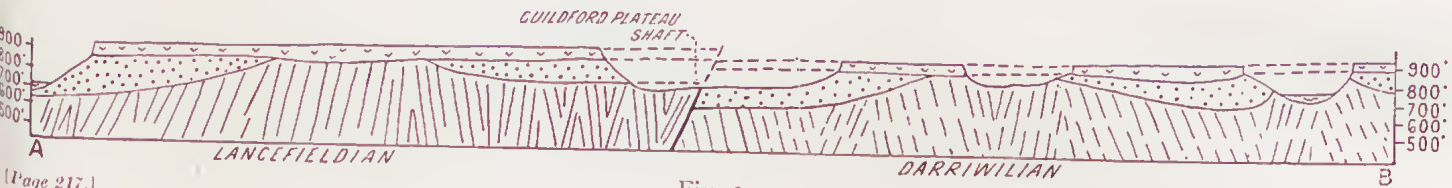

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Fig. 3.

(ii) Tertiary Rocks.

The Tertiary rocks are represented by the pre-basaltic auriferous wash and the basalt flows. Since the distribution of the wash and the basalt is connected with the Tertiary physiography, it becomes important to reconstruct as far as possible the early Tertiary topography.

(*a*) *Pre-basaltic Tertiary Gravels.*

These gravels range from a coarse conglomerate to fine sandy beds cemented by ferruginous material or quite unconsolidated. The thickness varies considerly, as might be expected from a fluviatile deposit laid down in a wide valley. The size of the boulders, their worn nature and their composition (vein quartz and quartzite predominate), afford information as to the velocity of the streams and the time needed for the deposition of the gravels. They must belong to a period when the climate was wetter and the relief more pronounced than at present. The gradient was steeper than at present, as east of Guildford the bed of the ancient stream is higher than the present Loddon, while further west it lies below the Loddon alluvium, as is shown in the workings of the Guildford Plateau mine.

West of the fault and south of Strangways railway station is an extensive area of exposed gravels, known as the Old Ironstone Diggings. This lies to the south of the Loddon, but probably represents a meander of the ancient Loddon as, immediately to the north, the basalt rests directly on bed-rock without any intervening gravel. The wash here was extensively worked, the sinking being comparatively deep—as far as one can gather from the old shafts and from information available, just over 100 feet. The surface level is about 800 feet so that the floor of the old valley would be under 700 feet. Immediately west of the Guildford Plateau mine the bottom of the wash is at a level of approximately 790 feet.

East of the fault the "bottom" lies below river level, and the mine workings show it to be about 675 feet above sea level. Further upstream the deepest part of the gravels is under the basalt, and its course can be traced roughly from the two shafts on the plateau, called the Old Plateau and New Plateau shafts, and by Cumings' and the Grand Trunk Tunnels.

Upstream from the Grand Trunk Tunnel the lead passed partly under the Loddon and here dredging yielded good results, and still further upstream it passed once more under the basalt, as is shown by the hillside workings. Here conflicting data make it difficult to reconstruct the course of the lead. The Forest Creek and Upper Loddon lead systems junctioned near the Guildford railway station (the "Guildford Gap") and flowed beneath the basalt. Two bores(14) near the north-east corner of Allot.

25, Guildford, proved the presence of auriferous wash at a depth of 200 feet—about the same level as on the worked lead to the south. A feasible explanation is that this is gravel deposited by a lateral stream developed on the northern side of the first basalt flow, but in the absence of full boring records this cannot be definitely asserted.

The Muckleford Lead lies along the Muckleford Creek and its upper part around Muckleford township has not been covered by basalt. Several tunnels have been driven from the valley of the Muckleford Creek to intercept the portion of this lead that lies beneath the basalt, the largest being Frenchman's Tunnel. (3, p. 131.) This tunnel proved that the course of the lead was very tortuous. The exact position of this lead is now being fixed by boring. While, as far as can be gathered, only the wash at the base of the gravel has been worked in the western part of this area, there is evidence of another run of consolidated auriferous wash or false bottom at a higher level in the east. (2, p. 26).

(b) Basalt Flows.

The main or upper basalt flow of the plateau is a dark greenish-grey, more or less vesicular rock, which in some places along the escarpment has a rough columnar structure, while a platy structure is developed elsewhere. Crystals of olivine and augite can be seen with the naked eye, the largest being about 2.5 mm. long. An older flow exposed near the Guildford Gap immediately underlies the younger flow, but it must extend a considerable distance downstream as both the old shafts on the plateau went through this flow.

The upper flow is composed essentially of olivine, pale brown augite, labradorite and iron ores. There is a marked tendency towards a glomero-porphyritic structure of the ferro-magnesian minerals and occasional felspar phenocrysts occur. The augite encloses small crystals of magnetite. The groundmass consists of granules of augite and olivine and rods and plates of magnetite, between the felspar laths which average 0.2 to 0.3 mm. in length. A fair amount of carbonate and occasional needles of apatite are present, and some olivine is altered to iddingsite.

The underlying basalt is on the whole finer-grained and less vesicular. Crystals of olivine up to 2.5 mm. in length alter to serpentine, not to iddingsite. Augite occurs as crystals up to 2 mm. long. The felspar is less acid than in the upper flow, some of the larger crystals giving symmetrical extinctions of 25°. Much interstitial felspar is untwinned or shows undulose extinction as in the oligoclase basalts, so that the affinities of this flow are with the basic mugearites. Some iron ore, apatite and carbonate are also present. The basalt flows which are in direct contact have a maximum thickness of over 75 feet.

(iii) Faulting.

The fault, which may be seen in the excavation at the mine, displaces the gravel nearly 100 feet. It is a reversed fault hading in the west at 70° on the surface, where it is 21 feet from the east side of the shaft, while at the 97-foot level it is 7 ft. 6 in. from the same side. The Ordovician rocks are bleached for about 10 feet from the fault while the blue mudstones are shattered. A very sharp syncline lies just to the west, and on this another fault can be seen which, however, does not affect the Tertiary rocks. Along the fault affecting the Tertiaries about 6 inches of coarse gravel may be seen representing auriferous wash caught up during the faulting movement as colours of gold may be obtained by panning. To the east the "gravel" is represented by clay bands, sandy beds, and some conglomerate, with an easterly dip of 30°. The flexure certainly seems to be due to the fault which has its upthrow side to the west. The floor on which the wash rests has been displaced vertically 100 feet (± 5 feet), as can be seen from the surface exposures and the level of the mine workings. Although the wash has been displaced 100 feet vertically, the basalt has been displaced rather less than 50 feet, indicating two movements along the fault line, each of about 50 feet. No other direct evidence of pre-basaltic faulting was seen, but the post-gravel physiography seems to show that movement caused by the fault interfered with the drainage system before the outpouring of the upper basalt flow. As a general rule the basalt flowed down the valley in which the gravel had been deposited. Lateral streams developed one on each side of the basalt, and have exposed pre-basaltic wash. The area of auriferous gravels in the neighbourhood of Shepherd's Flat was probably deposited at the junction of two broad valleys excavated by the pre-basaltic Loddon and Muckleford Creek in the soft Darriwilian bed-rock. To the west, however, the deposits at the Old Ironstone Diggings represent a large meander south of Strangways railway station, and show that the valley here was narrow and steep-sided. The basalt did not follow this meander, but flowed west and rejoined the old valley further down stream. It thus seems likely that changes of level due to movement along the fault caused the stream to cut through a low neck of bed-rock and abandon the meander, and it is through this gap that the basalt flowed. An alternative explanation is that a basalt covering of the Old Ironstone gravels has been completely denuded, but it is improbable that this is so since such a great amount of erosion locally would be hard to explain when compared with the smaller amount both up- and down-stream.

North of the Guildford Plateau mine the Quarter-sheet indicates by its hachuring a sudden change of level along a line corresponding with the hidden extension of the fault. On both sides of this line the basalt is similar, while the general slope of

the plateau surface on both sides is to the west in the general direction of the flow of the basalt, but in the opposite direction to the local slope shown by the hachures. Though the observed fault cannot be definitely identified with the Muckleford Fault, which as already stated is of much greater magnitude, it seems clear that it represents movement along the line of this greater fault. The Muckleford Fault displaces the Lower Ordovician beds vertically at least 4,000 feet, the auriferous wash is displaced 100 feet while the basalt has been displaced only 50 feet, thus showing at least three movements along the same line of weakness, the last movement being very recent.

V. Some late Tertiary Faults affecting Alluvial Workings in Victoria.

Late Tertiary faults play an important part in the geological history of eastern Australia. The existence of many faults has been inferred, and the following have been actually verified chiefly by underground mining operations. Nicholas (12), discussing the workings of the New Australian Company, Creswick, refers to a "well-formed vertical wash" 20 feet in height worked over a length of 200 feet, and states that no doubt it was the result of an upheaval. While this is a case where auriferous wash has been worked along the fault line, his statement that as a rule "there is a general absence of wash between the upper and lower part parallel to the cleavage" evidently means that faulting of wash is not uncommon; it is rarely that wash is found along the fault plane itself.

In 1917, E. J. Dunn(5) described a post-Tertiary fault at Beechworth, in a section which he had first noted in 1871(4) without realizing its significance. This fault is a thrust fault with a hade of 45° and a vertical displacement of about 20 feet. Dunn considers it to be of the same age as faults in the Berry Lead at Spring Hill and elsewhere near Allendale. W. Baragwanath(1) has recorded post-Newer Basalt faulting in the Ballarat area.

A late Tertiary fault affecting alluvial mining appears to be present in the Sebastian area(15), as H. S. Whitelaw reports, "Extremely good gold, it is said, was traced from near the Frederick the Great Company's main shaft westward to Myer's Creek, a distance of about a quarter of a mile where a sudden drop of 70 feet from 30 feet to 100 feet was encountered."

Harris states (personal communication) that the Whitelaw Fault at Bendigo—a fault in every way comparable with the Muckleford Fault—also shows evidence of post-Tertiary movement, auriferous gravels being carried 50 to 100 feet downwards on the Darriwilian side of the fault line.

These late Tertiary faults observed during mining operations are insignificant compared with those postulated in south-eastern Australia by physiographers and palaeo-geographers. Fenner (6), for example, finds evidence of two periods of Tertiary fault movements in the Bacchus Marsh area—the post-Older Basalt block faults and the post-Newer Basalt movement along the Rowsley Fault. Others have also explained the development of the physiography of this part of Australia by invoking faulting. (10. 13).

VI. Summary.

1. Reversed faulting has occurred along the line of the Muckleford Fault, with a hade to the west of approximately 70°.

2. Evidence based on graptolites from the east and west sides of the fault line, together with the estimated thickness of the Ordovician graptolite zones in this locality, indicates that the vertical displacement is of the order of 4.000 feet.

3. The greater part of this movement took place before the deposition of the pre-basaltic auriferous river gravels.

4. The movement continued in Tertiary times two late movements being observable, (i) of about 50 feet after the deposition of the gravels, but before the extrusion of the upper basalt flow, though probably after the lower flow, and (ii) of another 50 feet in post-basaltic times.

5. Similar Tertiary faults, including many of considerably greater magnitude, have been postulated to explain the physiography of south-eastern Australia or have been observed in mine workings elsewhere in Victoria.

References.

1. W. Baragwanath. The Ballarat Goldfield. *Mem. Geol. Surv. Vic.*, No. 14, p. 54.
2. *Dicker's Mining Journal*, 20th July, 1866, p. 26.
3. *Ibid.*, 20th February, 1866, p. 131.
4. E. J. Dunn. Notes on the Rocks and Minerals of the Ovens District. Rep. Min. Surveyors Vic. for quarter ending 31st Mar., 1871.
5. E. J. Dunn. A Post-Tertiary Fault at Beechworth. *Rec. Geol. Surv. Vic.*, iv. (1), 1917, p. 77.
6. C. Fenner. Physiography of the Werribee River Area. *Proc. Roy. Soc. Vic.*, n.s., xxxi. (1), 1918.
7. Geological Survey of Victoria. Quarter Sheet 15 N.E., 1864.
8. W. J. Harris. Palaeontological Sequence of the Lower Ordovician Rocks of the Castlemaine District. *Proc. Roy, Soc. Vic.*, n.s., xxiv. (1), 1916.
9. W. J. Harris and D. E. Thomas. Structure of the East Talbot Area. *Proc. Roy. Soc. Vic.*, n.s., xlvi. (2), 1934.

10. T. S. Hart. The Highlands and Main Divide of Western Victoria. *Proc. Roy. Soc. Vic.*, n.s., xx. (2), 1908.

11. J. T. Jutson. A Contribution to the Physiography of the Yarra River and Dandenong Creek Basins, Victoria. *Proc. Roy. Soc. Vic.*, n.s., xxiii., 1911.

12. W. Nicholas. *Quart. Rept. Min. Reg.* (Mines Dept. Vic.) for quarter ending 31st Mar., 1887, p. 71.

13. Griffith Taylor. The Australian Environment. Adv. Counc. for Sci. and Ind. (Australia) Mem. 1. Physiography of Eastern Australia. Com. Bureau of Meteorology, Bull. 8, 1911.

14. Third Report, Diamond Drills, Mines Dept. Vic., 1887, p. 44.

15. H. S. Whitelaw. Report on Sebastian Goldfield. *Mon. Prog. Rept. Geol. Surv. Vic.*, 1899, p. 4.